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Review

Uncharted waters: the rise of human-made aquatic environments in the age of the “Anthropocene”

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Highlights

- Water bodies of human origin have been multiplying throughout the “Anthropocene”.
- We propose a new term, “anthropohydrocosm”, to designate this diverse category of water bodies.

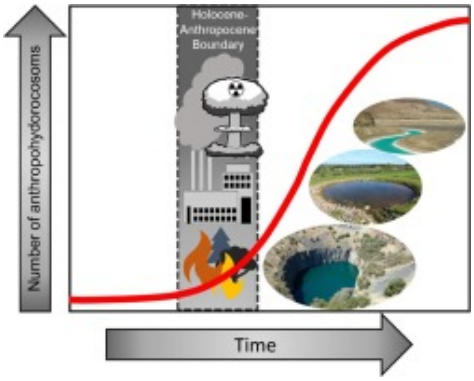
- Anthropohydrocosms influence the distribution of continental waters worldwide.
- Anthropohydrocosms play a role in global biogeochemical cycles and provide ecosystems services.
- Despite their human-made origin, these water bodies may be rich in biodiversity.

Abstract

Anthropogenic global change, including direct alteration of landscapes and rapid shifts in climate, is impacting existing aquatic resources negatively, but it is also giving rise to new water bodies. These changes are affecting the types, area and distribution of continental waters worldwide, and altering global biogeochemical cycles. In addition to the provisions that new aquatic systems can provide, their multiplication and diversification pose a global challenge regarding their management as aquatic resources and providers of diverse ecosystems services. They also offer opportunities to explore fundamental and applied ecological questions that can lead to a better understanding of ecosystem function in a rapidly changing world. This paper reviews the various types of human-made aquatic systems and proposes a new term: “anthropohydrocosms”, to designate and contextualize them within the concept of the “Anthropocene”. We also develop a classification scheme and briefly discuss the challenge of assessing their importance in providing sustainable ecosystem services.

Graphical abstract

Anthropohydrocosms, aquatic systemsthat owe their inception to deliberate or unintentional human impact, have been multiplying throughout the “Anthropocene”.



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Introduction

Globally, the freshwater environment is mutating at an alarming rate due to multiple stressors (Ormerod et al., 2010). Lakes, ponds, and rivers constitute less than 2% of Earth’s non-oceanic area (Downing et al., 2006), but nonetheless, freshwaters represent one of the planet’s richest pools of biodiversity (Dudgeon et al., 2006). Yet, they are also among the most degraded and imperiled ecosystems as they are increasingly under threat from human pressures (Vörösmarty et al., 2010; Carpenter et al., 2011). For example, there has been a staggering 81% decline in freshwater vertebrate populations monitored between 1970 and 2012 (WWF Living Planet Report, 2016). Many inland water bodies are currently vanishing due to warmer and drier climate, to mismanagement, or a combination of both (Ravilious, 2016). Worldwide, freshwater availability is changing in response to over-use by humans and anthropogenic climate change, with terrestrial water storage trending below previous ranges (Rodell et al., 2018).

Whereas disappearing surface waters often receive much press coverage because of the catastrophic nature and consequences of these events (see for example, a recent case of “river piracy” in western North America; Shugar et al., 2017), we more seldom hear about cases where aquatic environments are appearing. Although it has been assessed that there has been a net loss of freshwater versus land area across the Earth’s surface over the past 30 years (about 58 000 km^2), many regions, most notably South and East Asia and Amazonia, have seen their aquatic area coverage increase (Donchyts et al., 2016). For example, assessment using the Aqua Monitor tool (Donchyts et al., 2016) revealed the appearance of 1180 km^2 of water in Myanmar between 1985 and 2010, linked with the construction of dams and reservoirs. Moreover, Lehner et al. (2011) have estimated that about 16.7 million reservoirs larger than 0.01 ha potentially represent an area of terrestrial surface water of more than 305 000 km^2.

Humans have been impacting and modifying existing aquatic systems throughout their history. Early human impacts on continental aquatic systems are temporally and spatially very heterogenous (see Dubois et al., 2017) but impacts that are increasingly global in scope, such as widespread cultural eutrophication, are concurrent with the mid-19th to mid-20th century. Humans have also been creating aquatic systems to accommodate their needs throughout history. The end uses of these anthropogenic aquatic systems are numerous and varied. They include (but are not limited to) water supply, flood control, irrigation, land drainage, hydropower, recreational opportunities, navigational pathways, fisheries and aquaculture. As the global human population has increased at exponential rates, especially since the mid-20th century, so has its need for freshwater and aquatic resources (e.g. Postel et al., 1996). Consequently, the number of human-made aquatic systems has increased accordingly. A prime example of this is the increase in the capacity of large reservoirs built throughout the 20th century (Fig. 1).

Regardless of the boundary that will officially be assigned to the start of the Anthropocene, this epoch will likely include an exponential increase in human-made aquatic systems, probably following the general trend of the mid-20th century Great Acceleration (Steffen et al., 2015). The effects of this reorganisation of the hydrosphere, which are conceivably multifaceted and highly significant for the whole of the Earth's functioning, remain relatively unknown. With this review of human-made aquatic systems, our objectives are to (1) bring attention to the importance and diversity of these systems by naming the concept and placing it within a classification scheme and (2) to spark interest in their study and management and invite discussions on the topic within the context of the "Anthropocene".

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Section snippets

Classification of anthropogenic continental aquatic systems based on genesis and ontogeny

Because of the vital services that freshwaters provide, humans have always settled preferentially near rivers, lakes, and wetlands, thereby significantly altering continental aquatic resources throughout history. Anthropogenic modification of all types of continental waters has lead to changes in their distribution, numbers, shapes, sizes, dynamics, physicochemical properties, biodiversity, and functions (e.g. Downing et al. 2006 and Downing, 2010 and references therein). Moreover, with an …

The hand of humans: anthropogenic environmental modification and the creation of aquatic ecosystems

Environmental modification by humans resulting in the inception of anthropohydrocosms, whether it is intentional or not, is present worldwide and in many forms. The physical setting for the appearance of anthropohydrocosms is often rapidly put into place, within a few days to a few years. However, the developmental trajectory towards functioning ecosystems in these spaces can be highly variable and depends on multiple environmental and human factors. The following section presents different …

Outstanding questions and future avenues for anthropohydrocosm research

Clearly, anthropohydrocosms have the potential to provide humans with a plethora of provisioning, regulating, supporting and cultural services (see Table 1). However, because they can also induce unwanted consequences, they need to be closely planned and managed to ensure that their net effects are positive and that their potential benefits are maximized. For example, net effects of the multiplication of anthropohydrocosms on the global hydrological cycle is a question that needs to be …

Valuation of ecosystem services: a price tag on anthropohydrocosms

The goods and services provided by aquatic ecosystems are numerous; from simple esthetics to essential water and food provision. What are the marketable and non-marketable losses related to the destruction of aquatic environments as a result of urban development, farming, or mining, just to name a few? How much money are we willing to invest in the conservation and rehabilitation of aquatic environments, or in the creation of new ones? Putting price tags on ecosystem services is an increasingly …

Conclusion

Anthropohydrocosms constitute one of the most important human impacts on our planet. They are often the result of activities and disturbances that are at some level questionable or that can have adverse effects on one or more components of the environment or of society but can in time come to represent a valuable resource providing ecosystem services. The need exisits to more closely study and manage all aspects related to them.

In the context of environmental research, management and …

Acknowledgements

We thank Stéphane Boudreau and Stéphane Campeau for fruitful discussions on the subject of Anthropohydrocosms and two anonymous reviewers for their constructive comments. …

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2022, Journal of Molecular Liquids

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Scientific and stakeholder evidence-based assessment: Ecosystem response to floating solar photovoltaics and implications for sustainability

2021, Renewable and Sustainable Energy Reviews

> *Citation Excerpt :*
>
> …The differences in stakeholder-identified relative opportunities and threats of FPVs for water bodies indicates the complexity in resolving deployments for specific water body types and integrating ecosystem service impact with management and design decisions [137]. For example, balancing the delivery of ecosystem services beyond the provision of drinking water from a water supply reservoir, such as recreational and leisure opportunities [133,138] and disservices such as greenhouse gas emissions, which increase the rate of global warming [139,140]. Moreover, understanding the impacts in light of FPV designs, host water body characteristics, and management goals will be critical to maximise the opportunities and minimise the threats posed by FPVs [115].…

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The value artificial lake ecosystems provide to recreational anglers: Implications for management of biodiversity and outdoor recreation

2019, Journal of Environmental Management

> *Citation Excerpt :*
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> …Among small lakes, gravel pits form a substantial component in many cultural European landscapes (e.g., Emmrich et al., 2014; Zhao et al., 2016; Søndergaard et al., 2018; Matern et al., 2019). These artificial ecosystems are often relatively recent in origin (<100 years of age, Schurig, 1972; Gee, 1978; Wright, 1990; Zhao et al., 2016) and were created by mining of sand, clay, gravel and other resources (Søndergaard et al., 2018; Saulnier-Talbot and Lavoie, 2018). Gravel pits, as other man-made ecosystems such as ponds or reservoirs, support diverse communities of animals and plants and are increasingly important for conservation of aquatic and other water-related biodiversity (e.g., De Meester et al., 2005; Søndergaard et al., 2018; Oertli, 2018; Clifford and Heffernan, 2018; Werneke et al., 2018; Matern et al., 2019).…

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Greenhouse gas flux from stormwater ponds in southeastern Virginia (USA)

2019, Anthropocene

> *Citation Excerpt :*
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> …The scope of this conclusion is potentially worldwide, as freshwater “anthropohydrocosms” such as stormwater ponds are created for urban planning projects globally (Saulnier-Talbot and Lavoie, 2018).…

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Ecological and conservation value of small standing-water ecosystems: A systematic review of current knowledge and future challenges

2019, Water Switzerland

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